CLAIMS

What is claimed is:

1. An apparatus for storing data, said apparatus comprising:

a fixed electrode electrically coupled to

a2

a storage medium having a multiplicity of different and distinguishable oxidation states wherein data is stored in said oxidation states by the addition or withdrawal of one or more electrons from said storage medium via the electrically coupled electrode.

2. The apparatus of claim 1, wherein said storage medium stores data at a density of at least one bit per molecule.

3. The apparatus of claim 1, wherein said storage medium comprises a molecule having at least two different and distinguishable oxidation states.

4. The apparatus of claim 1, wherein said storage medium comprises a molecule having at least eight different and distinguishable oxidation states.

5. The apparatus of claim 1, wherein said storage medium is covalently linked to said electrode.

6. The apparatus of claim 1, wherein said storage medium is electrically coupled to said electrode through a linker

7. The apparatus of claim 1, wherein said storage medium is covalently linked to said electrode through a linker.

8. The apparatus of claim 7, wherein said linker is a thiol linker.

9. The apparatus of claim 1, wherein said storage medium is juxtaposed in the proximity of said electrode such that electrons can pass from said storage medium to said electrode.

10. The apparatus of claim 1, wherein said storage medium is juxtaposed to a dielectric material imbedded with counterions.

11. The apparatus of claim 1, wherein said storage medium and said electrode are fully encapsulated in an integrated circuit.

12. The apparatus of claim 1, wherein said storage medium is electronically coupled to a second fixed electrode that is a reference electrode.

13. The apparatus of claim 1, wherein said storage medium is present on a single plane in said device.

14. The apparatus of claim 1, wherein said storage medium is present at a multiplicity of storage locations.

15. The apparatus of claim 14, wherein said storage locations are present on a single plane in said device.

16. The apparatus of claim 14, wherein said apparatus comprises multiple planes and said storage locations are present on multiple planes of said device.

17. The apparatus of claim 14, wherein said storage locations range from about 1024 to about 4096 different locations.

18. The apparatus of claim 17, wherein each location is addressed by a single electrode.

19. The apparatus of claim 17, wherein each location is addressed by two electrodes.

20. The apparatus of claim 1, wherein said electrode is connected to a voltage source.

21. The apparatus of claim 20, wherein said voltage source is the output of an integrated circuit.

22. The apparatus of claim 1, wherein said electrode is connected to a device to read the oxidation state of said storage medium.

23. The apparatus of claim 22, wherein said device is selected from the group consisting of a voltammetric device, an amperometric device, and a potentiometric device.

24. The apparatus of claim 23, wherein said device is an impedance spectrometer or a sinusoidal voltammeter.

25. The apparatus of claim 22, wherein said device provides a Fourier transform of the output signal from said electrode.

26. The apparatus of claim 22, wherein said device refreshes the oxidation state of said storage medium after reading said oxidation state.

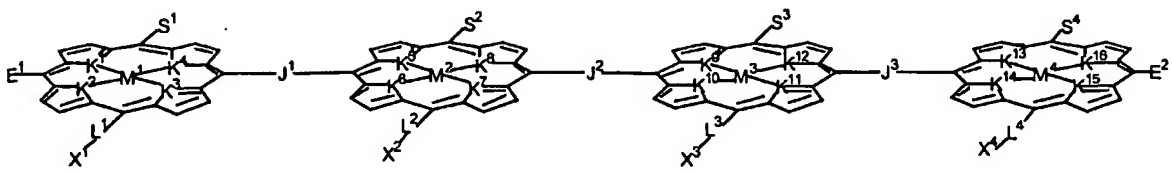
27. The apparatus of claim 1, wherein said different and distinguishable oxidation states of said storage medium can be set by a voltage difference no greater than about 2 volts.

28. The apparatus of claim 1, wherein said storage medium is selected from the group consisting of a porphyrinic macrocycle, a metallocene, a linear polyene, a cyclic polyene, a heteroatom-substituted linear polyene, a heteroatom-substituted cyclic polyene, a tetrathiafulvalene, a tetraselenafulvalene, a metal coordination complex, a buckyball, a triarylamine, a 1,4-phenylenediamine, a xanthene, a flavin, a phenazine, a phenothiazine, an acridine, a quinoline, a 2,2'-bipyridyl, a 4,4'-bipyridyl, a tetrathiotetracene, and a *peri*-bridged naphthalene dichalcogenide.

29. The apparatus of claim 28, wherein said storage medium comprises a molecule selected from the group consisting of a porphyrin, an expanded porphyrin, a contracted porphyrin, a ferrocene, a linear porphyrin polymer, and a porphyrin array.

30. The apparatus of claim 29, wherein said storage medium comprises a porphyrinic macrocycle substituted at a β- position or at a *meso*- position.

31. The apparatus of claim 29, wherein said storage medium comprises a molecule having the formula:



wherein

S^1, S^2, S^3, and S^4 are substituents independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

M^1, M^2, M^3, and M^4 are independently selected metals;

K^1, K^2, K^3, K^4, K^5, K^6, K^7, K^8, K^9, K^{10}, K^{11}, K^{12}, K^{13}, K^{14}, K^{15}, and K^{16} are independently selected from the group consisting of N, O, S, Se, Te, and CH;

J^1, J^2, and J^3 are independently selected linkers;

L^1, L^2, L^3, and L^4 are present or absent and, when present are independently selected linkers;

X^1, X^2, X^3, and X^4 are independently selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate;

and E^1 and E^2 are terminating substituents selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts; and

said molecule has at least two different and distinguishable oxidation states.

32. The apparatus of claim 31, wherein said molecule has at least eight different and distinguishable oxidation states.

33. The apparatus of claim 31, wherein M^1, M^2, M^3, and M^4 are independently selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Al, Ga, Pb, and Sn.

34. The apparatus of claim 31, wherein J^1, J^2, and J^3 are independently selected from the group consisting of 4,4'-diphenylethyne, 4,4'-diphenylbutadiyne, 4,4'-biphenyl, 1,4-phenylene, 4,4'-stilbene, 1,4-bicyclooctane, 4,4'-azobenzene, 4,4'-benzylideneaniline, and 4,4"-terphenyl.

35. The apparatus of claim 31, wherein L^1-X^1, L^2-X^2, L^3-X^3, and L^4-X^4 are independently present or absent and, when present, are independently selected from the group consisting of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

36. The apparatus of claim 32, wherein

K^1, K^2, K^3, K^4, K^5, K^6, K^7, K^8, K^9, K^{10}, K^{11}, K^{12}, K^{13}, K^{14}, K^{15}, and K^{16} are the same;

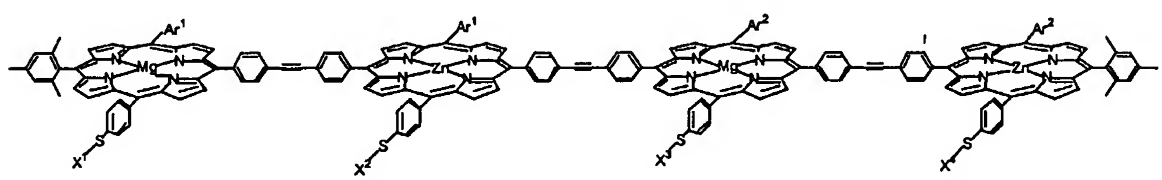
M^1 and M^3 are the same;

M^2 and M^4 are the same and different from M^1 and M^3;

S^1 and S^2 are the same; and

S^3 and S^4 are the same and different from S^1 and S^2.

37. The apparatus of claim 31, wherein said apparatus comprises a molecule having the formula:



wherein

Ar^1 and Ar^2 are independently aromatic groups; and

X^1, X^2, X^3, and X^4 are independently selected from the group consisting of H or a substrate.

38. The apparatus of claim 31, wherein said storage medium comprises a porphyrinic macrocycle containing at least two porphyrins of equal energies held apart from each other at a spacing less than about 50 Å such that said molecule has an odd hole oxidation state permitting the hole to hop between said two porphyrins and wherein said

odd hole oxidation state is different from and distinguishable from another oxidation state of said porphyrinic macrocycle.

39. The apparatus of claim 29, wherein said storage medium comprises a molecule having the formula:

$$\begin{array}{ccc} P^1 & & P^4 \\ | & & | \\ J^1 & & J^3 \\ | & & | \\ P^2 & \text{—}Q\text{—} & P^5 \\ | & & | \\ J^2 & & J^4 \\ | & & | \\ P^3 & & P^6 \end{array}$$

wherein J^1, J^2, J^3, and J^4 are independently selected linkers that permit electron transfer between the porphyrinic macrocycles;

P^1 and P^2 are porphyrinic macrocycles selected to have the same oxidation state;

P^4 and P^6 are porphyrinic macrocycles selected to have the same oxidation state;

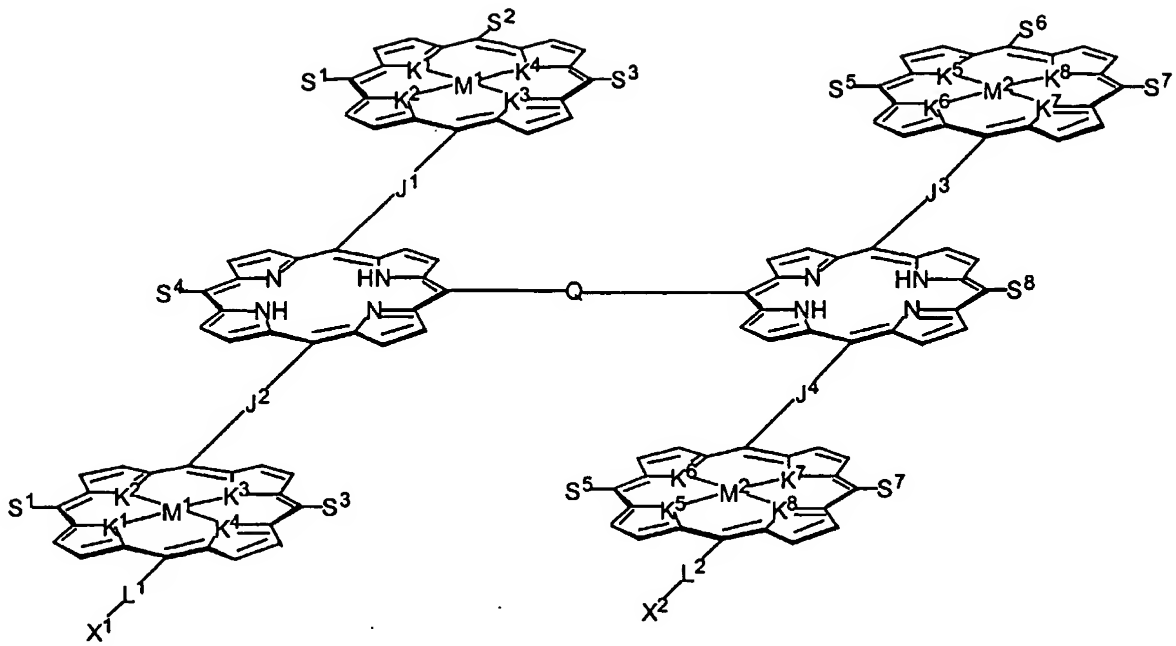
P^2 has an oxidation potential greater than the oxidation potential of P^1 or P^3;

P^5 has an oxidation potential greater than the oxidation potential of P^4 or P^6; and

Q is a linker.

40. The apparatus of claim 39, wherein Q is selected from the group consisting of 1,4-bis(4-terphen-4"-yl)butadiyne or a tetrakis(arylethyne), a linker comprising 1,12-carboranyl ($C_2B_{10}H_{12}$), 1,10-carboranyl ($C_2B_8H_{10}$), [*n*]staffane, 1,4-cubanediyl, 1,4-bicyclo[2.2.2]octanediyl, phenylethynyl, and a linker comprising a *p*-phenylene unit.

41. The apparatus of claim 39, wherein said storage medium comprises a molecule having the formula:



wherein

M^1 and M^2 are independently selected metals;

S^1, S^2, S^3, S^4, S^5, S^6, S^7, and S^8 are independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl;

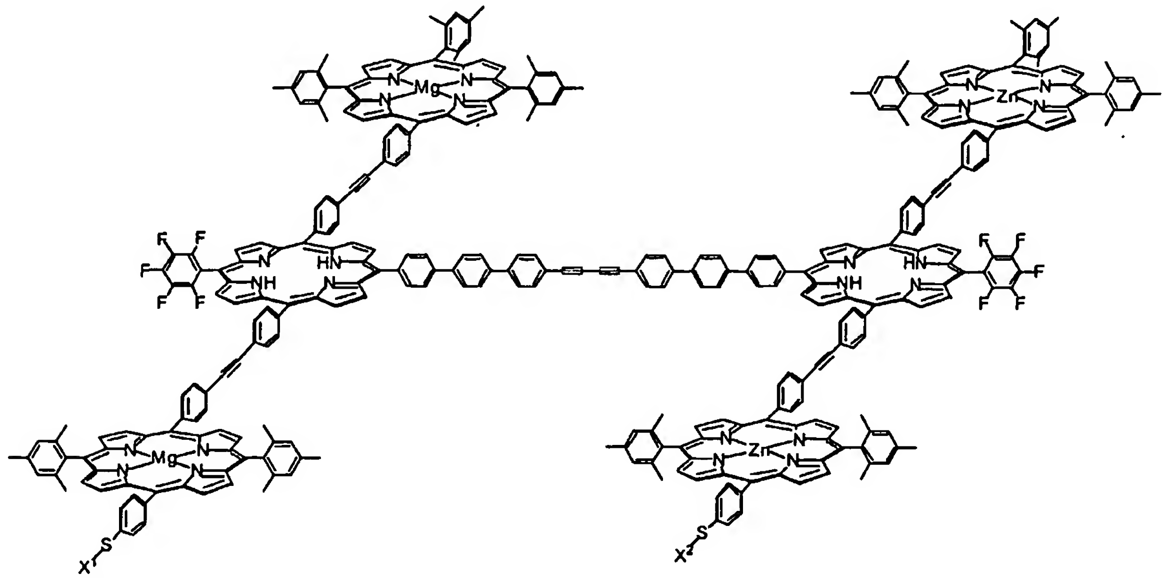
K^1, K^2, K^3, K^4, K^5, K^6, K^7, and K^8 are independently selected from the group consisting of are independently selected from the group consisting of N, O, S, Se, Te, and CH;

L^1 and L^2 are independently selected linkers; and

X^1 and X^2 are independently selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

42. The apparatus of claim 41, wherein
S^1, S^2, S^3, S^5, S^6, and S^7 are the same;
S^4 and S^8 are the same;
K^1, K^2, K^3, K^4, K^5, K^6, K^7, and K^8 are the same
J^1, J^2, J^3 and J^4 are the same; and
M^1 and M^2 are different.

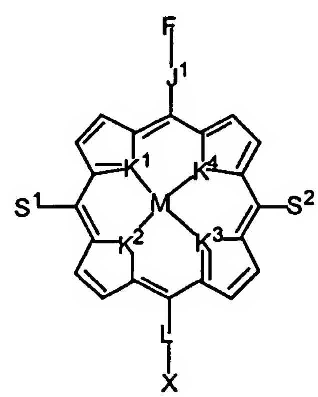
43. The apparatus of claim 42, wherein said storage medium comprises a molecule having the formula:



wherein X^1 and X^2 are independently selected from the group consisting of H and a substrate.

44. The apparatus of claim 29, wherein said storage medium comprises a molecule having three different and distinguishable oxidation states.

45. The apparatus of claim 44, wherein said molecule has the formula:



wherein

F is selected from the group consisting of a ferrocene, a substituted ferrocene, a metalloporphyrin, and a metallochlorin;

J^1 is a linker;

M is a metal;

S^1 and S^2 are independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

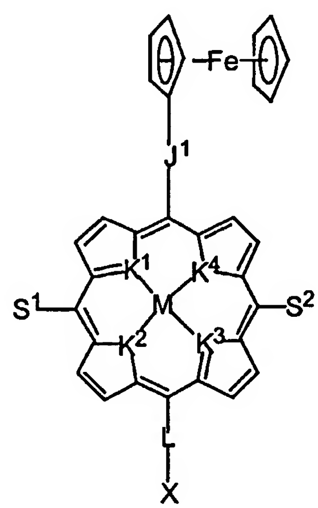
K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, S, O, Se, Te, and CH;

L is a linker; and

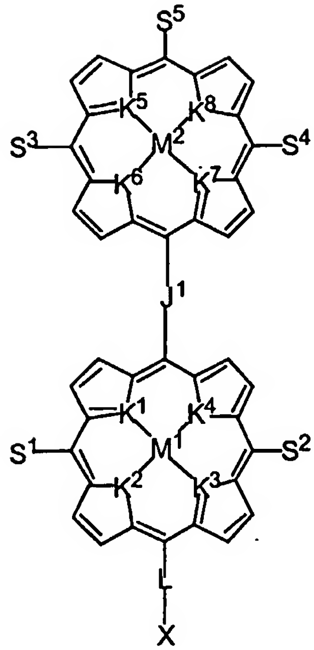
and X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate;

and said molecule has at least three different and distinguishable oxidation states.

46. The apparatus of claim 45, wherein said molecule has the formula:



47. The apparatus of claim 45, wherein said molecule has the formula:



wherein

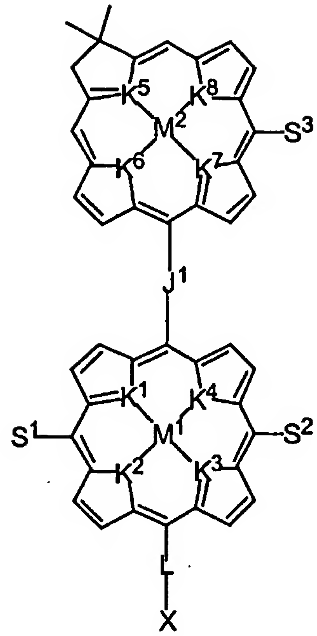
M^2 is a metal;

K^5, K^6, K^7, and K^8 are independently selected from the group consisting of N, S, O, Se, Te, and CH;

S^3, S^4, and S^5 are independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts; and

L-X is selected from the group consisting of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

48. The apparatus of claim 45, wherein said molecule has the formula:



wherein

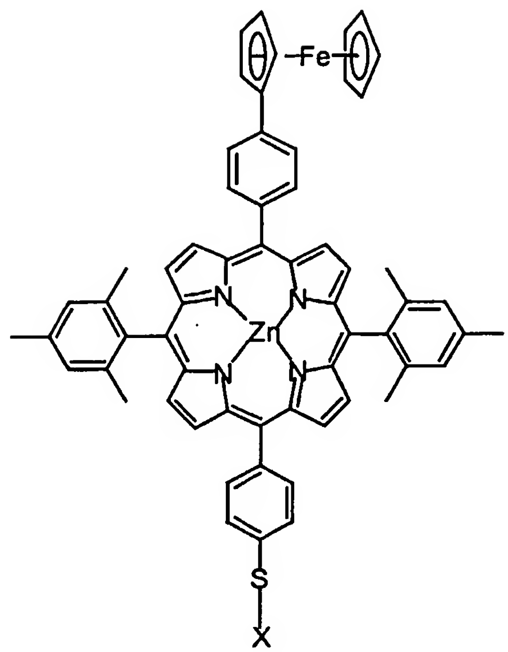
M^2 is a metal;

K^5, K^6, K^7, and K^8 are independently selected from the group consisting of N, O, S, Se, Te, and CH;

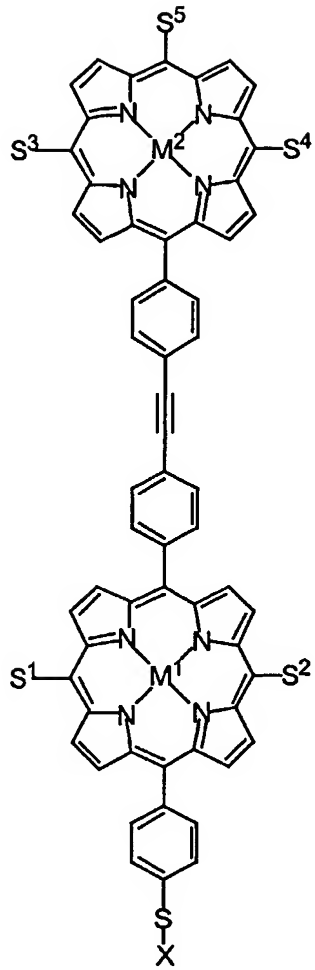
S3 is selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts and

L-X is selected from the group consisting of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

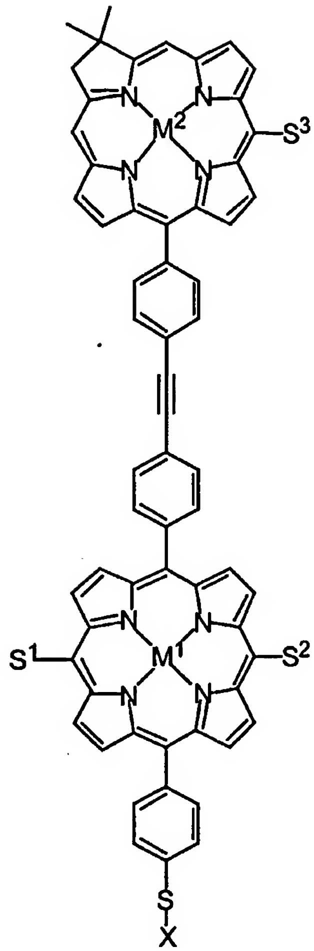
49. The apparatus of claim 46, wherein said molecule is



50. The apparatus of claim 47, wherein said molecule is

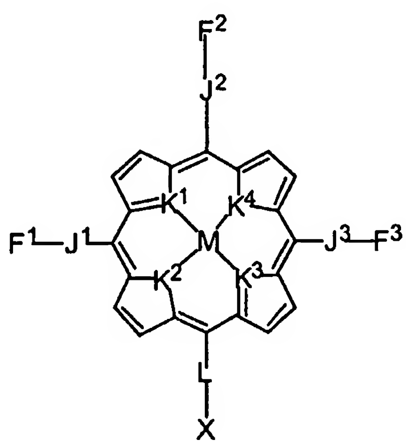


51. The apparatus of claim 48, wherein said molecule is



52. The apparatus of claim 29, wherein said storage medium comprises a molecule having five different and distinguishable oxidation states.

53. The apparatus of claim 52, wherein said molecule has the formula:



wherein

M^1 is a metal;

F^1, F^2, and F^3 are independently selected ferrocenes or substituted ferrocenes;

J^1, J^2, and J^3 are independently selected linkers;

K1, K2, K3, and K4 are independently selected from the group consisting of N, O, S, Se, Te, and CH; L is a linker; and

X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

54. The apparatus of claim 53, wherein

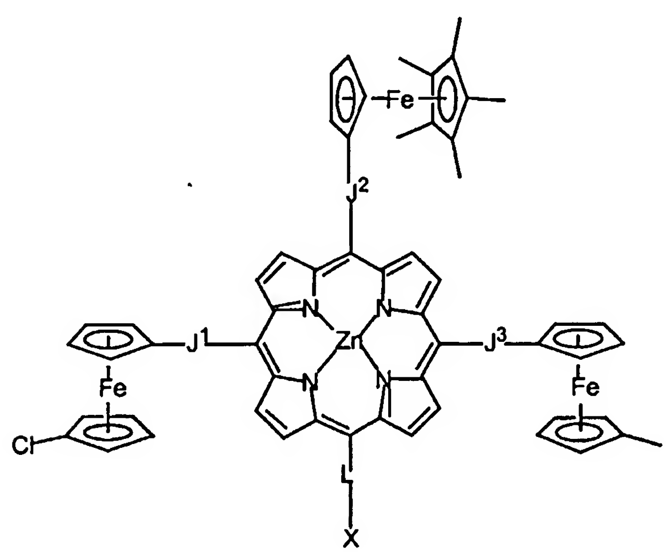
K^1, K^2, K^3 and K^4 are the same;

M^1 is a metal selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Pb, Al, Ga, and Sn;

J^2, J^2, and J^3 are the same; and

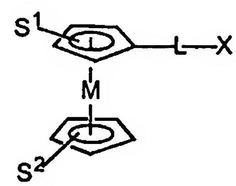
F^1, F^2, and F^3 are all different.

55. The apparatus of claim 54, wherein said molecule is



56. The apparatus of claim 45, wherein J^1, J^2, and J^3 are selected from the group consistin g of 4,4'-diphenylethyne, 4,4'-diphenylbutadiyne, 4,4'-biphenyl, 1,4-phenylene, 4,4'-stilbene, 1,4-bicyclooctane, 4,4'-azobenzene, 4,4'-benzylideneaniline, and 4,4"-terphenyl.

57. The apparatus of claim 29, wherein said storage medium comprises a molecule having the formula:



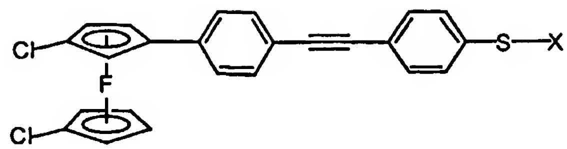
wherein L is a linker;

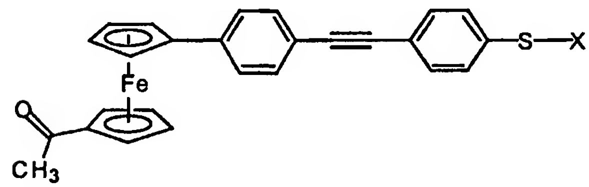
M is a metal;

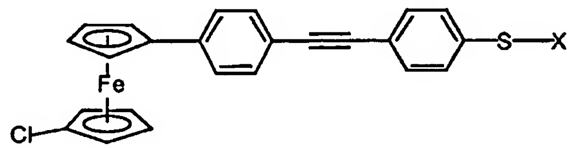
S^1 and S^2 are independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts; and

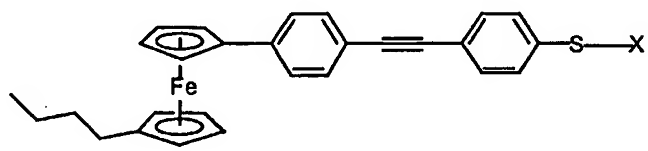
X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

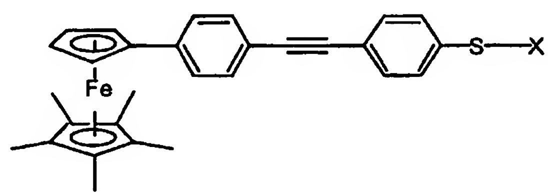
58. The apparatus of claim 57, wherein said molecule is selected from the group consisting of:

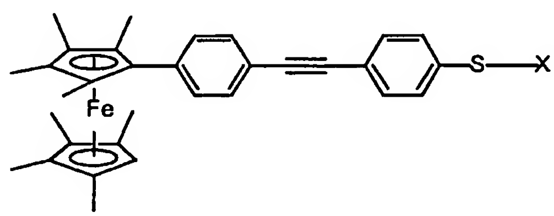












wherein X is a substrate.

59. The apparatus of claim 57, wherein -L-X is selected from the group consisting of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

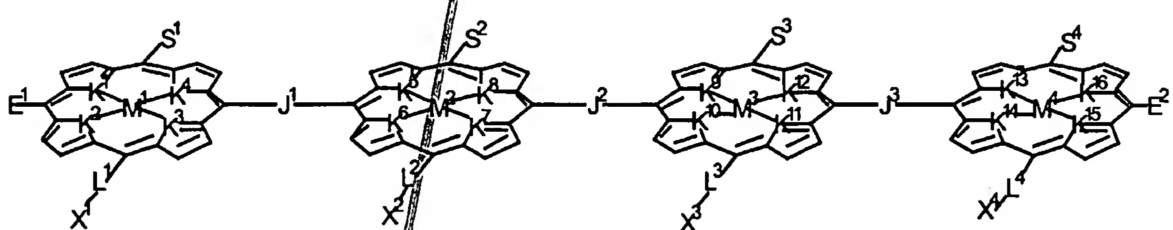
60. An information storage medium, said storage medium comprising a one or more storage molecules such that said storage medium has at least two different and distinguishable non-neutral oxidation states.

61. The storage medium of claim 60, wherein said storage molecule is selected from the group consisting of a porphyrinic macrocycle, a metallocene, a linear polyene, a cyclic polyene, a heteroatom-substituted linear polyene, a heteroatom-substituted cyclic polyene, a tetrathiafulvalene, a tetraselenafulvalene, a metal coordination complex, a buckyball, a triarylamine, a 1,4-phenylenediamine, a xanthene, a flavin, a phenazine, a phenothiazine, an acridine, a quinoline, a 2,2'-bipyridyl, a 4,4'-bipyridyl, a tetrathiotetracene, and a peri-bridged naphthalene dichalcogenide.

62. The storage medium of claim 61, wherein said storage medium comprises a sto rage molecule selected from the group consisting of a porphyrin, an expanded porphyrin, a contracted porphyrin, a ferrocene, a linear porphyrin polymer, and a porphyrin array.

63. The storage medium of claim 62, comprising a storage molecule that contains two or more covalently linked redox-active subunits.

64. The storage medium of claim 63, wherein said storage molecule has a the formula:



wherein

S^1, S^2, S^3 and S^4 are substituents independently selected from the group consistin g of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

M^1, M^2, M^3, and M^4 are independently selected metals;

K^1, K^2, K^3, K^4, K^5, K^6, K^7, K^8, K^9, K^{10}, K^{11}, K^{12}, K^{13}, K^{14}, K^{15}, and K^{16} are independently selected from the group consisting of N, O, S, Se, Te, and CH;

J^1, J^2, and J^3 are independently selected linkers;

L^1, L^2, L^3, and L^4 are present or absent and, when present are independently selected linkers;

and X^1, X^2, X^3, and X^4 are independently selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate;

and E^1 and E^2 are terminating substituents; and

said molecule has at least two different and distinguishable oxidation states.

65. The storage medium of claim 64, wherein said storage molecule has at least eight different and distinguishable non-neutral oxidation states.

66. The storage medium of claim 65, wherein

K^1, K^2, K^3, K^4, K^5, K^6, K^7, K^8, K^9, K^{10}, K^{11}, K^{12}, K^{13}, K^{14}, K^{15}, and K^{16} are the same;

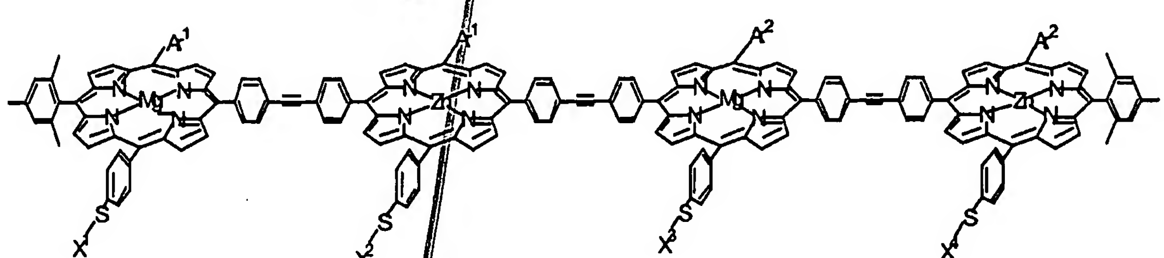
M^1 and M^3 are the same;

M^2 and M^4 are the same and different from M^1 and M^3;

S^1 and S^2 are the same; and

S^3 and S^4 are the same and different from S^1 and S^2.

67. The storage medium claim 66, wherein said storage molecule has the formula:



wherein

Ar^1 and Ar^2 are independently aromatic groups; and

X^1, X^2, X^3, and X^4 are independently selected from the group consisting of H or a substrate.

68. The storage medium of claim 62, wherein said storage molecule is a porphyrinic macrocycle containing a metallo-free porphyrin and having an odd hole oxidation state permitting the hole to hop between two subunits of said porphyrinic macrocycle and wherein said odd hole oxidation state is different from and distinguishable from another oxidation state of said porphyrinic macrocycle.

69. The storage medium of claim 68, wherein said storage molecule has the formula:

$$\begin{array}{ccccc} P^1 & & & & P^4 \\ | & & & & | \\ J^1 & & & & J^3 \\ | & & & & | \\ P^2 & — & Q & — & P^5 \\ | & & & & | \\ J^2 & & & & J^4 \\ | & & & & | \\ P^3 & & & & P^6 \end{array}$$

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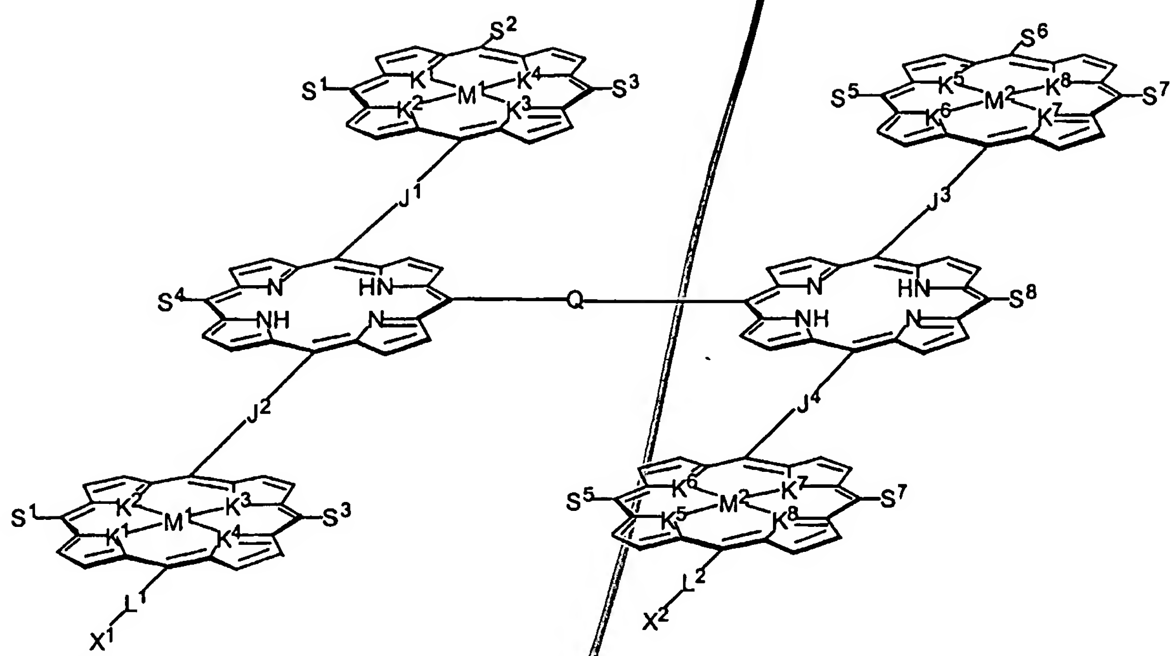
wherein J^1, J^2, J^3, and J^4 are independently selected linkers that permit electron transfer between the porphyrinic macrocycles;

P^1, P^3, P^4, and P^6 are independently selected porphyrinic macrocycles;

P^2 and P^5 are independently selected metallo-free porphyrinic macrocycles; and

Q is a linker.

70. The storage medium of claim 69, wherein said storage molecule has the formula:



wherein

M^1 and M^2 are independently selected metals;

S^1, S^2, S^3, S^4, S^5, S^6, S^7, and S^8 are independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl;

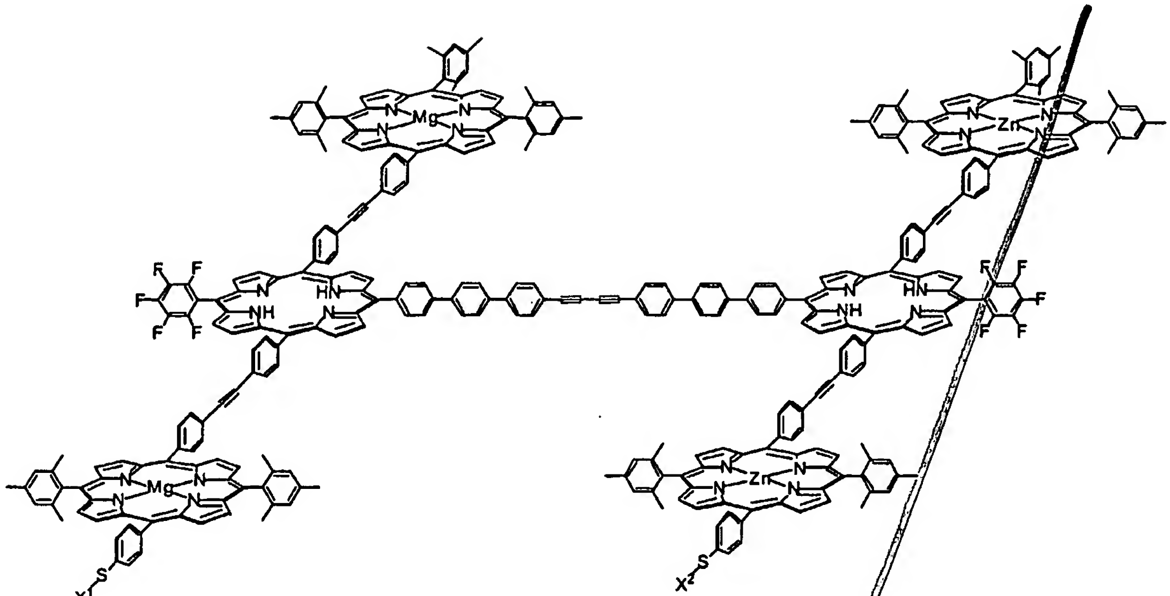
K^1, K^2, K^3, K^4, K^5, K^6, K^7, and K^8 are independently selected from the group c onsisting of are independently selected from the group consisting of N, O, S, Se, Te, and CH;

L^1 and L^2 are independently selected linkers; and

X^1 and X^2 are independently selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

71. The storage medium of claim 70, wherein
S^1, S^2, S^3, S^5, S^6, and S^7 are the same;
K^1, K^2, K^3, K^4, K^5, K^6, K^7, and K^8 are the same
J^1, J^2, J^4 and J^5 are the same; and
M^1 and M^2 are different.

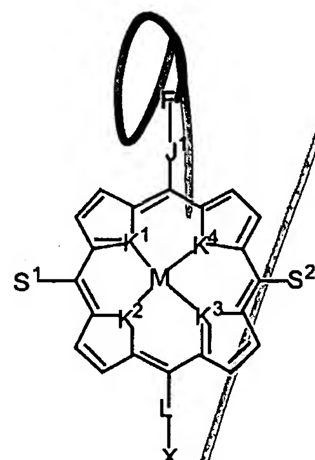
72. The storage medium of claim 71, wherein said storage molecule has the formula:



wherein X^1 and X^2 are independently selected from the group consisting of H and a substrate.

73. The storage medium of claim 62, wherein said storage molecule has three different and distinguishable non-neutral oxidation states.

74. The storage medium of claim 73, wherein said storage molecule has the formula:



wherein

F^1 is selected from the group consisting of a ferrocene, a substituted ferrocene, a metalloporphyrin, and a metallochlorin;

J^1 is a linker;

M^1 is a metal;

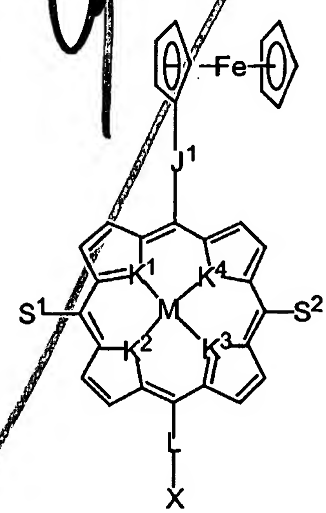
S^1 and S^2 are substituents independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, O, S, Se, Te, and CH;

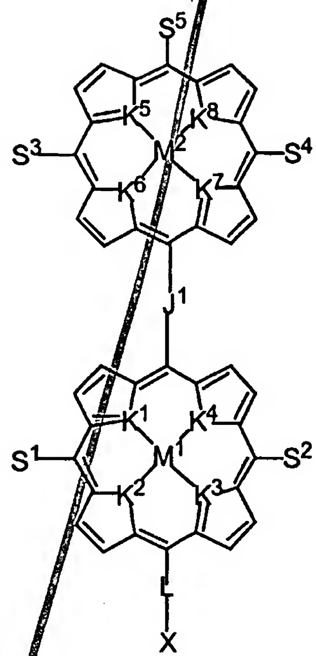
L is a linker; and

X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate, and said molecule has at least three different and distinguishable oxidation states.

75. The storage medium of claim 74, wherein said storage molecule has the formula:



76. The storage medium of claim 74, wherein said storage molecule has the formula:



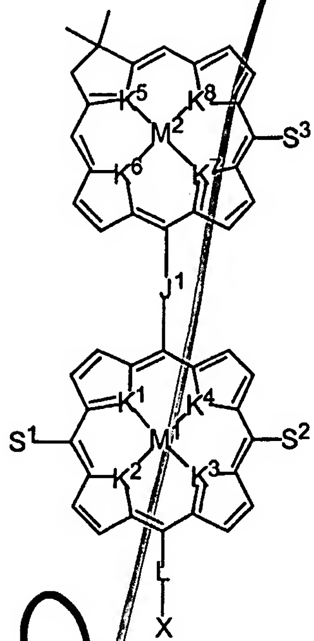
wherein

M^2 is a metal;

K^5, K^6, K^7, and K^8 are independently selected from the group consisting of N, O, S, Se, Te, and CH;

S^3, S^4, and S^5 are independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts.

77. The storage medium of claim 74, wherein said storage molecule has the formula:



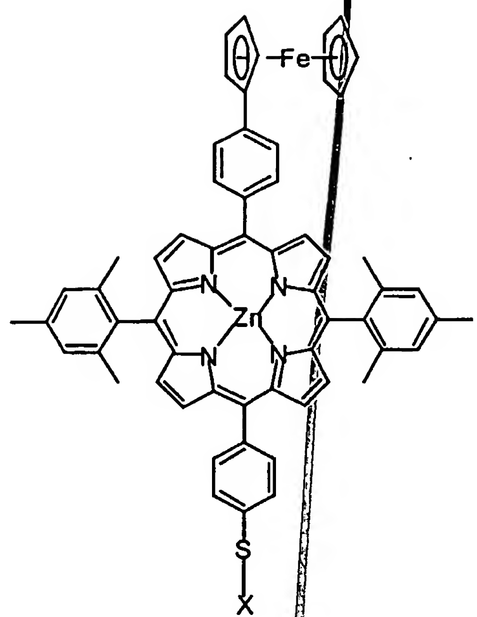
wherein

M^2 is a metal;

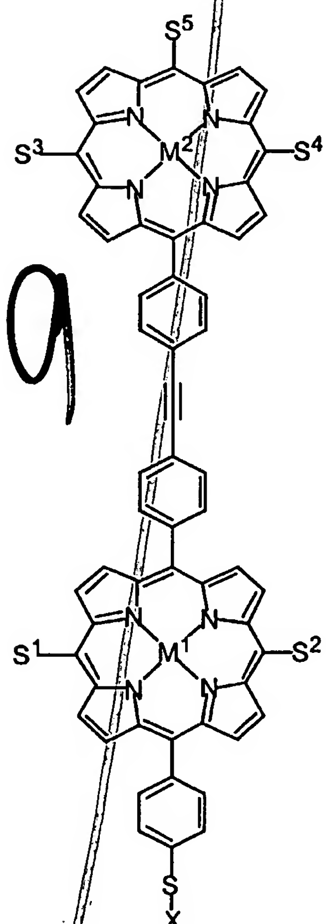
K^5, K^6, K^7, and K^8 are independently selected from the group consisting of N, O, S, Se, Te, and CH;

S^3 is selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts.

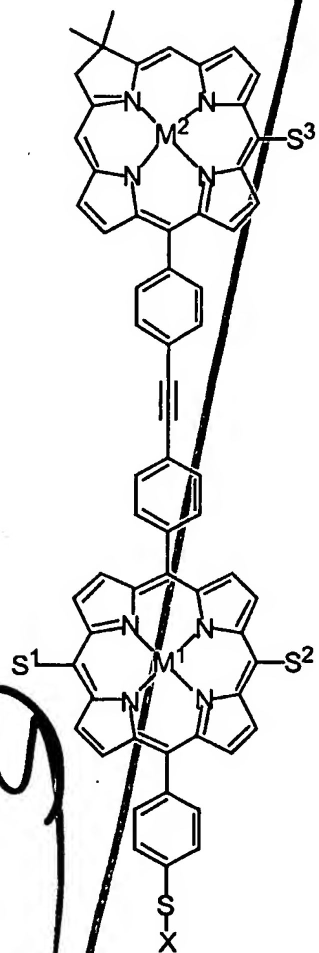
78. The storage medium of claim 75, wherein said storage molecule has the formula:



79. The storage medium of claim 76, wherein said storage molecule has the formula:

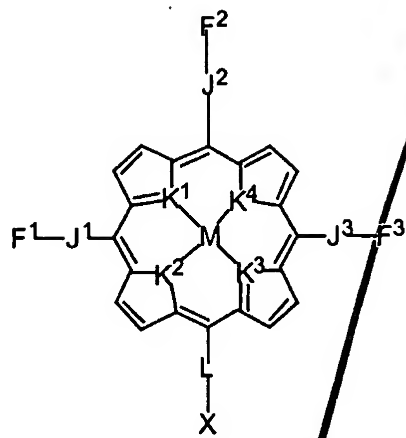


80. The storage medium of claim 77, wherein said storage molecule has the formula:



81. The storage medium of claim 62, wherein said storage molecule has five different and distinguishable non-neutral oxidation states.

82. The storage medium of claim 81, wherein said storage molecule has the formula:



wherein

M is a metal;

F^1, F^2, and F^3 are independently selected ferrocenes or substituted ferrocenes;

J^1, J^2, and J^3 are independently selected linkers;

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, O, S, Se, Te, and CH;

L is a linker; and

X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

83. The storage medium of claim 82, wherein

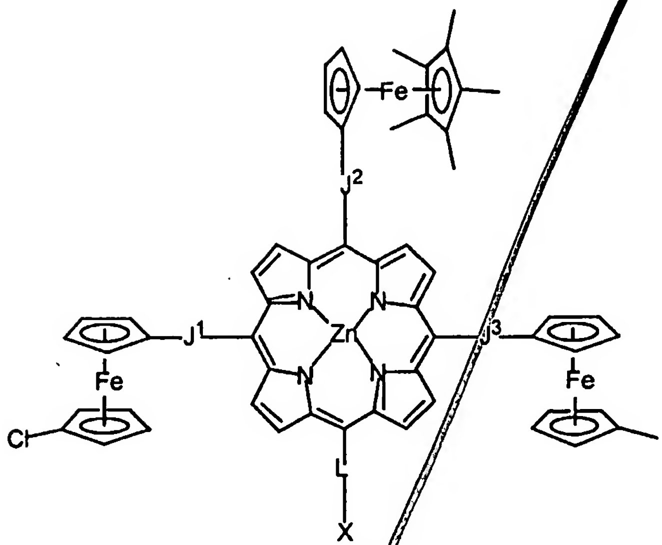
K^1, K^2, K^3 and K^4 are the same;

M is a metal selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Al, Pb, Ga, and Sn;

J^2, J^2, and J^3 are the same; and

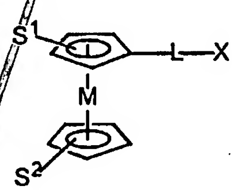
F^1, F^2, and F^3 are all different.

84. The storage medium of claim 83, wherein said molecule is



85. The storage medium of claim 82, wherein J^1, J^2, and J^3 are selected from the group consisting of 4,4'-diphenylethyne, 4,4'-diphenylbutadiyne, 4,4'-biphenyl, 1,4-phenylene, 4,4'-stilbene, 1,4-bicyclooctane, 4,4'-azobenzene, 4,4'-benzylideneaniline, and 4,4"-terphenyl.

86. The storage medium of claim 62, wherein said storage molecule has the formula:



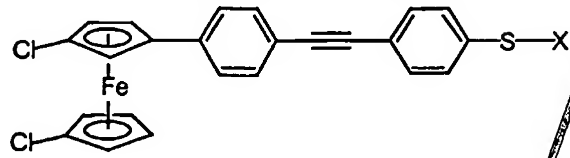
wherein M is a metal;

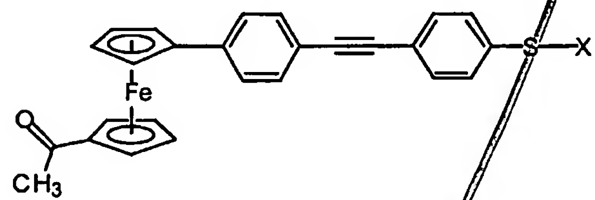
S^1 and S^2 are selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

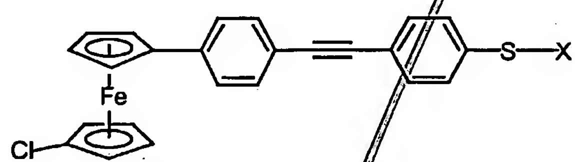
L is a linker; and

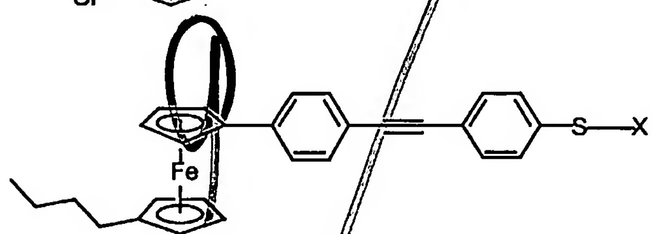
X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

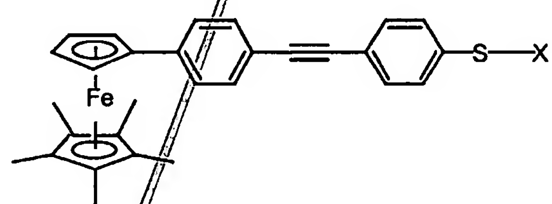
87. The storage medium of claim 86, wherein said storage molecule has a formula selected from the group consisting of:

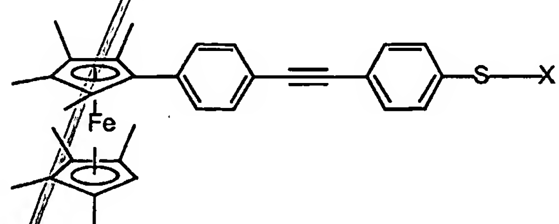












88. The storage medium of claim 86, wherein -L-X is selected from the group consistin g of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-

hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

89. The storage medium of claim 60, wherein each storage molecule is present at a discrete storage location on a substrate.

90. The storage medium of claim 60, wherein the storage molecule is in contact with a dielectric material imbedded with counterions.

91. The storage medium of claim 60, wherein said storage molecule comprises two or more covalently linked redox-active subunits.

92. A collection of molecules for the production of a data storage medium, said collection comprising a plurality storage molecules wherein each species of storage molecule has an oxidation state different from and distinguishable from the oxidation states of the other species of storage molecules comprising said collection.

93. The collection of claim 92, wherein said collection of molecules comprising a plurality of porphyrinic macrocycle species, wherein each species has an oxidation state different from and distinguishable from the oxidation states of every other species of porphyrinic macrocycle in said collection.

94. A molecule for the storage of information, said molecule having the formula:

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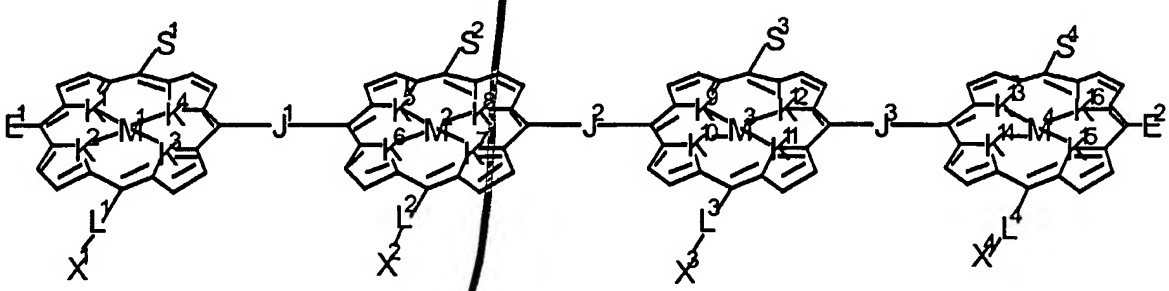


wherein

S^1, S^2, S^3, and S^4 are substituents independently selected from the group consistin g of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl,

sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

M^1, M^2, M^3, and M^4 are independently selected metals;

K^1, K^2, K^3, K^4, K^5, K^6, K^7, K^8, K^9, K^{10}, K^{11}, K^{12}, K^{13}, K^{14}, K^{15}, and K^{16} are independently selected from the group consisting of N, O, S, Se, Te, and CH;

J^1, J^2, and J^3 are independently selected linkers;

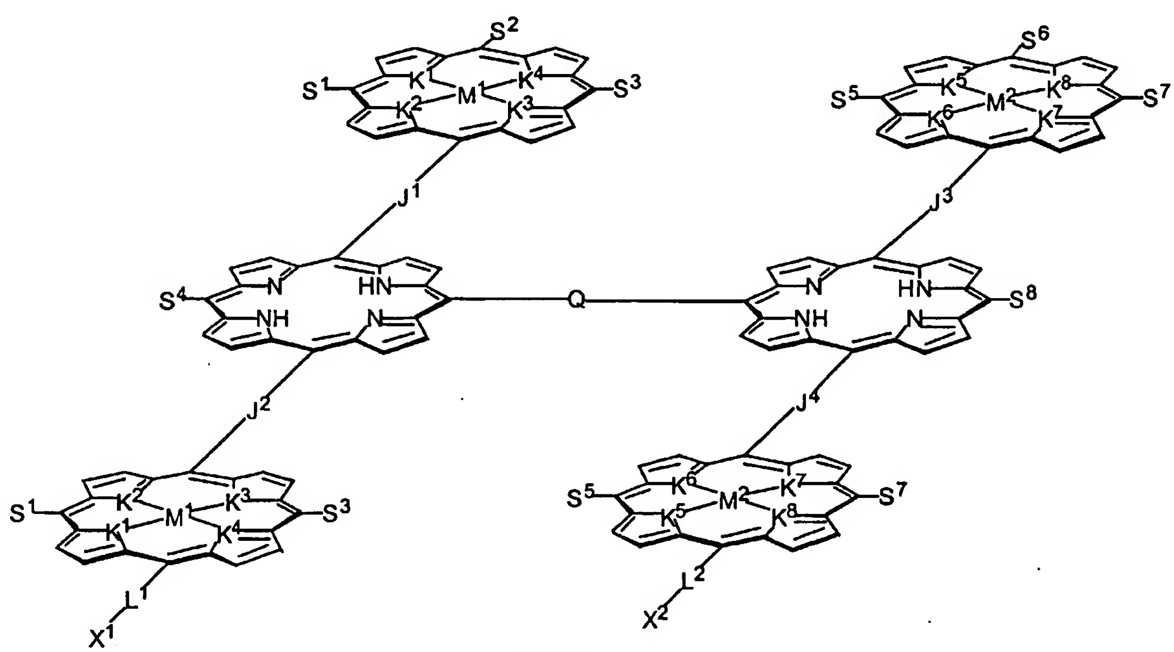
L^1, L^2, L^3, and L^4 are present or absent and, when present are independently selected linkers;

and X^1, X^2, X^3, and X^4 are independently selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate;

and E^1 and E^2 are terminating substituents; and

said molecule has at least two different and distinguishable oxidation states.

95. A molecule for the storage of information, said molecule having the formula:



wherein

M^1 and M^2 are independently selected metals;

S^1, S^2, S^3, S^4, S^5, S^6, S^7, and S^8 are independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio,

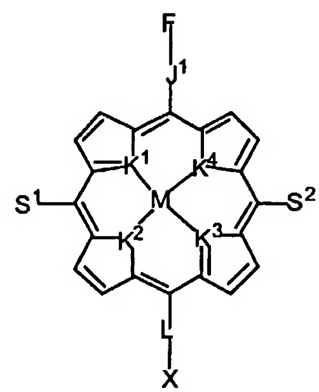
perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl;

K^1, K^2, K^3, K^4, K^5, K^6, K^7, and K^8 are independently selected from the group consisting of are independently selec ted from the group consisting of N, O, S, Se, Te, and CH;

L^1 and L^2 are independently selected linkers; and

X^1 and X^2 are independently selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

96. A molecule for the storage of information, said molecule having the formula:



F^1 is selected from the group consisting of a ferrocene, a substituted ferrocene, a metalloporphyrin, and a metallochlorin;

J^1 is a linker;

M is a metal;

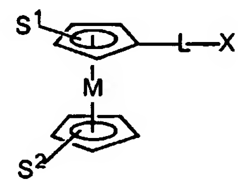
S^1 and S^2 are substituents independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, O, S, Se, Te, and CH;

L is a linker; and

X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate, and said molecule has at least three different and distinguishable oxidation states.

97. A molecule for the storage of information, said molecule having the formula:



wherein M is a metal;

S^1 and S^2 are selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

L is a linker; and

X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate.

98. A method of storing data, said method comprising:

i) providing an apparatus according to claim 1; and

ii) applying a voltage to said electrode at sufficient current to set an oxidation state of said storage medium.

99. The method of claim 98, wherein said voltage ranges up to about 2 volts.

100. The method of claim 98, wherein said voltage is the output of an integrated circuit.

101. The method of claim 98, wherein said voltage is the output of a logic gate.

117. The apparatus of claim 116, wherein said storage medium stores data at a density of at least one bit per molecule.

118. The apparatus of claim 116, wherein said storage medium has at least two different and distinguishable non-neutral oxidation states.

119. The apparatus of claim 116, wherein said storage medium has at least eight different and distinguishable oxidation states.

120. The apparatus of claim 116, wherein said storage molecule is covalently linked to said electrode.

121. The apparatus of claim 116, wherein said storage molecule is electrically coupled to said electrode through a linker.

122. The apparatus of claim 116, wherein said storage molecule is covalently linked to said electrode through a linker.

123. The apparatus of claim 122, wherein said linker is a thiol linker.

124. The apparatus of claim 116, wherein said storage medium is juxtaposed in the proximity of said electrode such that electrons can pass from said storage medium to said electrode.

125. The apparatus of claim 116, wherein said storage medium is juxtaposed to a dielectric material imbedded with counterions.

126. The apparatus of claim 116, wherein said storage medium and said electrode are fully encapsulated in an integrated circuit.

127. The apparatus of claim 116, wherein said storage medium is electronically coupled to a second fixed electrode that is a reference electrode.

128. The apparatus of claim 116, wherein said storage medium is present on a single plane in said device.

129. The apparatus of claim 116, wherein said storage medium is present at a multiplicity of storage locations.

130. The apparatus of claim 129, wherein said storage locations are present on a single plane in said device.

131. The apparatus of claim 129, wherein said apparatus comprises multiple planes and said storage locations are present on multiple planes of said device.

132. The apparatus of claim 129, wherein said storage locations range from about 1024 to about 4096 different locations.

133. The apparatus of claim 129, wherein each location is addressed by a single electrode.

134. The apparatus of claim 129, wherein each location is addressed by two electrodes.

135. The apparatus of claim 116, wherein said electrode is connected to a voltage source.

136. The apparatus of claim 135, wherein said voltage source is the output of an integrated circuit.

137. The apparatus of claim 116, wherein said electrode is connected to a device to read the oxidation state of said storage medium.

138. The apparatus of claim 137, wherein said device is selected from the group consisting of a voltammetric device, an amperometric device, and a potentiometric device.

139. The apparatus of claim 137, wherein said device is an impedance spectrometer or a sinusoidal voltammeter.

140. The apparatus of claim 137, wherein said device provides a Fourier transform of the output signal from said electrode.

141. The apparatus of claim 137, wherein said device refreshes the oxidation state of said storage medium after reading said oxidation state.

142. The apparatus of claim 116, wherein said different and distinguishable oxidation states of said storage medium can be set by a voltage difference no greater than about 2 volts.

143. The apparatus of claim 116, wherein M is selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Al, Pb, Ga, and Sn.

144. The apparatus of claim 116, wherein M is selected from the group consisting of Zn, Mg, and (H,H).

145. The apparatus of claim 116, wherein S is selected from the group consisting of mesityl, C_6F_5, 2,4,6-trimethoxyphenyl, and *n*-pentyl.

146. The apparatus of claim 116, wherein X is selected from the group consisting of CONH(Et), $COCH_3$, and H.

147. The apparatus of claim 116, wherein L-X is selected from the group consisting of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

148. The apparatus of claim 116, wherein
S^1, S^2, and S^3 are all the same;
K^1, K^2, K^3, and K^4 are all N; and
L is p-thiophenyl.

149. The apparatus of claim 148, wherein M is Zn or (H,H).

150. The apparatus of claim 149, wherein S^1, S^2, and S^3 are selected from the group consisting of mesityl, C_6F_5, 2,4,6-trimethoxyphenyl, and *n*-pentyl.

151. The apparatus of claim 149, wherein X is selected from the group consisting of CONH(Et), $COCH_3$, and H.

152. An apparatus for storing data, said apparatus comprising:
a fixed electrode electrically coupled to a storage medium comprising a molecule having the formula:

102. The method of claim 98, further comprising detecting the oxidation state of said storage medium and thereby reading out the data stored therein.

103. The method of claim 102, wherein said detecting the oxidation state of the storage medium further comprises refreshing the oxidation state of the storage medium.

104. The method of claim 102, wherein said detecting comprises analyzing a readout signal in the time domain.

105. The method of claim 102, wherein said detecting comprises analyzing a readout signal in the frequency domain.

106. The method of claim 105, wherein said detecting comprises performing a Fourier transform on said readout signal.

107. The method of claim 102, wherein said detecting utilizes a voltammetric method.

108. The method of claim 102, wherein said detecting utilizes impedance spectroscopy.

109. The method of claim 102, wherein said detecting comprises exposing said storage medium to an electric field to produce an electric field oscillation having characteristic frequency and detecting said characteristic frequency.

110. The method of claim 98, wherein said storage medium comprises a molecule selected from the group consisting of a porphyrinic macrocycle, a metallocene, a linear polyene, a cyclic polyene, a heteroatom-substituted linear polyene, a heteroatom-substituted cyclic polyene, a tetrathiafulvalene, a tetraselenafulvalene, a metal coordination complex, a buckyball, a triarylamine, a 1,4-phenylenediamine, a xanthene, a flavin, a phenazine, a phenothiazine, an acridine, a quinoline, a 2,2'-bipyridyl, a 4,4'-bipyridyl, a tetrathiotetracene, and a *peri*-bridged naphthalene dichalcogenide.

111. The method of claim 110, wherein said storage medium comprises a molecule selected from the group consisting of a porphyrin, an expanded porphyrin, a contracted porphyrin, a ferrocene, a linear porphyrin polymer, and a porphyrin array.

112. The method of claim 110, wherein said storage medium comprises a porphyrinic macrocycle substituted at a β- position or at a *meso-* position.

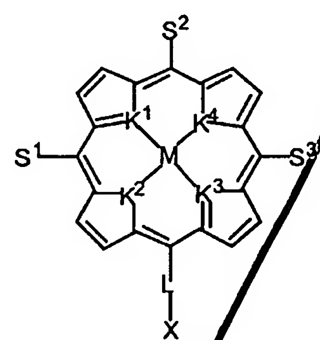
113. The method of claim 110, wherein said molecule has at least eight different and distinguishable oxidation states.

114. In a computer system, a memory device, said memory device comprising the apparatus of claim 1.

115. A computer system comprising a central processing unit, a display, a selector device, and a memory device, said memory device comprising the apparatus of claim 1.

~~116. An apparatus for storing data, said apparatus comprising:~~

~~a fixed electrode electrically coupled to a storage medium comprising a storage molecule having the formula:~~



94

~~wherein~~

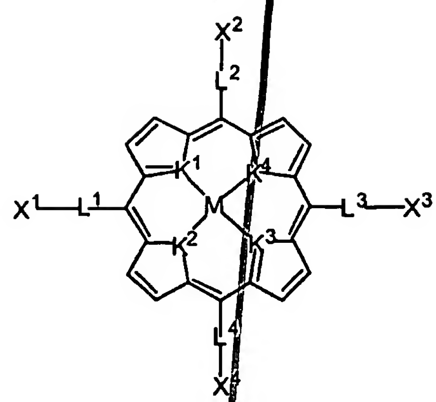
~~K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, O, S, Se, Te, and CH;~~

~~M is a metal or (H,H);~~

~~S^1, S^2, and S^3 are indepently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, alkoxy, halogen, alkylthio, alkoxy, perfluoroalkyl, perfluoroaryl, pyidyl, nitrile, nitro, amino, and alkylamino;~~

~~L is present or absent and, when present, is a linker; and~~

~~X is a substrate or a reactive site that can covalently or ionically couple to a substrate.~~



wherein

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, S, O, Se, Te, and CH;

M is a metal or (H,H);

L^1, L^2, and L^3, and L^4 are independently present or absent and, when present, are a linkers; and

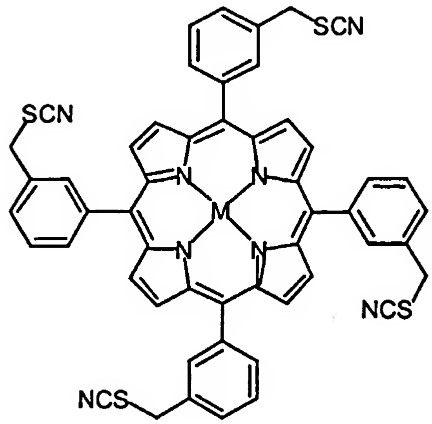
X^1, X^2, X^3, and X^4 are independently present or absent and, when present, independently a substrate or a reactive site that can covalently or ionically couple to a substrate.

153. The apparatus of claim 152, wherein M is selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Pb, Al, Ga, and Sn.

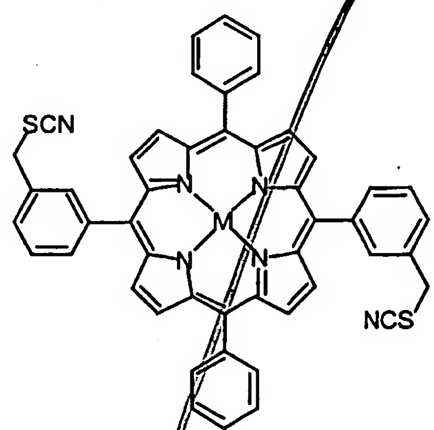
154. The apparatus of claim 152, wherein M is selected from the group consisting of Zn, Mg, and (H,H).

155. The apparatus of claim 152, wherein L^1-X^1, L^2-X^2, L^3-X^3, and L^4-X^4 are independently present or absent and, when present, are independently selected from the group consisting of 3-mercaptophenyl, 3-mercaptomethylphenyl, 3-(2-(4-mercaptophenyl)ethynyl)phenyl, 3-(2-(3-mercaptomethylphenyl)ethynyl)phenyl, 3-hydroselenophenyl, 3-hydroselenomethylphenyl, 3-(2-(4-hydroselenophenyl)ethynyl)phenyl, 3-(2-(3-hydroselenophenyl)ethynyl)phenyl, 3-hydrotellurophenyl, 3-hydrotelluromethylphenyl and 3-(2-(4-hydrotellurophenyl)ethynyl)phenyl, and 3-(2-(3-hydrotellurophenyl)ethynyl)phenyl.

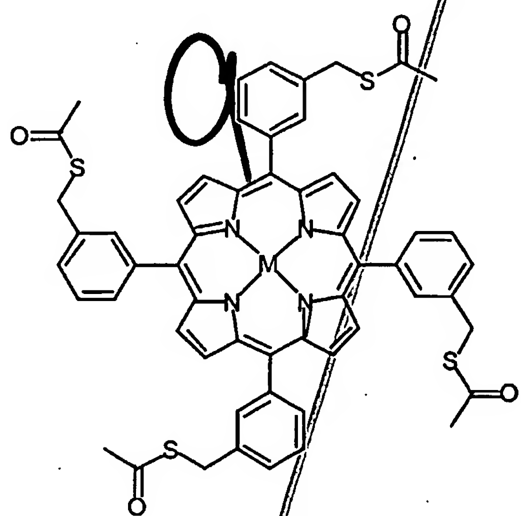
156. The apparatus of claim 152, wherein said storage medium comprises a molecule having a formula selected from the group consisting of:



M = H,H; Zn

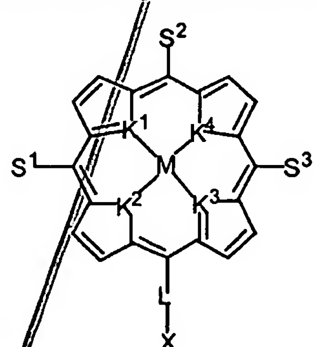


M = H,H; Zn



M = H,H; Zn

157. An information storage molecule, said molecule having the formula:



wherein

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, S, O, Se, Te, and CH;

M is a metal or (H,H);

S^1, S^2, and S^3 are independently selected frm the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts;

L is present or absent and, when present, is a linker; and

X is a substrate or a reactive site that can covalently or ionically couple to a substrate.

158. The molecule of claim 157, wherein M is selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Al, Pb, Ga, and Sn.

159. The molecule of claim 157, wherein M is selected from the group consisting of Zn, Mg, and (H,H).

160. The molecule of claim 157, wherein S is selected from the group consisting of mesityl, C_6F_5, 2,4,6-trimethoxyphenyl, and *n*-pentyl.

161. The molecule of claim 157, wherein X is selected from the group consisting of gold, silver, copper, CONH(Et), $COCH_3$, and H.

162. The molecule of claim 157, wherein L-X is selected from the group consisting of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

163. The molecule of claim 157, wherein

S^1, S^2, and S^3 are all the same;

K^1, K^2, K^3, and K^4 are all N; and

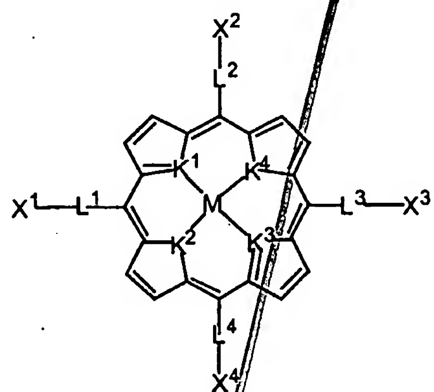
L is p-thiophenyl.

164. The molecule of claim 163, wherein M is Zn or (H,H).

165. The molecule of claim 164, wherein S^1, S^2, and S^3 are selected from the group consisting of mesityl, C_6F_5, 2,4,6-trimethoxyphenyl, and *n*-pentyl.

166. The molecule of claim 164, wherein X is selected from the group consisting of SCONH(Et), $SCOCH_3$, and SH.

167. An information storage molecule, said molecule having the formula:



wherein

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, O, S, Se, Te, and CH;

M is a metal or (H,H);

S^1, S^2, and S^3 are indepently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, alkoxy, halogen, alkylthio, alkoxy, perfluoroalkyl, perfluoroaryl, pyridyl, nitrile, nitro, amino, and alkylamino;

L^1, L^2, and L^3, and L^4 are independently present or absent and, when present, are linkers; and

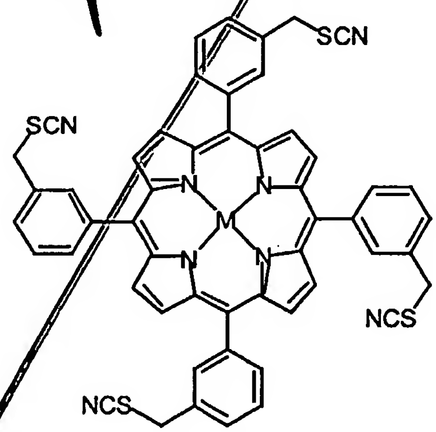
X^1, X^2, X^3, and X^4 are independently present or absent and, when present, independently a substrate or a reactive site that can covalently or ionically couple to a substrate.

168. The molecule of claim 167, wherein M is selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Al, Pb, Ga, and Sn.

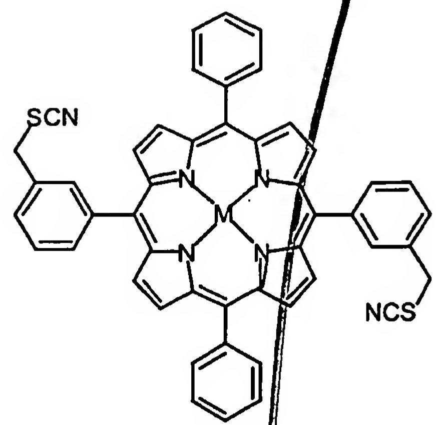
169. The molecule of claim 167, wherein M is selected from the group consisting of Zn, Mg, and (H,H).

170. The molecule of claim 167, wherein L^1-X^1, L^2-X^2, L^3-X^3, and L^4-X^4 are independently present or absent and, when present, are independently selected from the group consisting of 3-mercaptophenyl, 3-mercaptomethylphenyl, 3-(2-(4-mercaptophenyl)ethynyl)phenyl, 3-(2-(3-mercaptomethylphenyl)ethynyl)phenyl, 3-hydroselenophenyl, 3-hydroselenomethylphenyl, 3-(2-(4-hydroselenophenyl)ethynyl)phenyl, 3-(2-(3-hydroselenophenyl)ethynyl)phenyl, 3-hydrotellurophenyl, 3-hydrotelluromethylphenyl and 3-(2-(4-hydrotellurophenyl)ethynyl)phenyl, and 3-(2-(3-hydrotellurophenyl)ethynyl)phenyl.

171. The molecule of claim 167, wherein said storage medium comprises a molecule having a formula selected from the group consisting of:

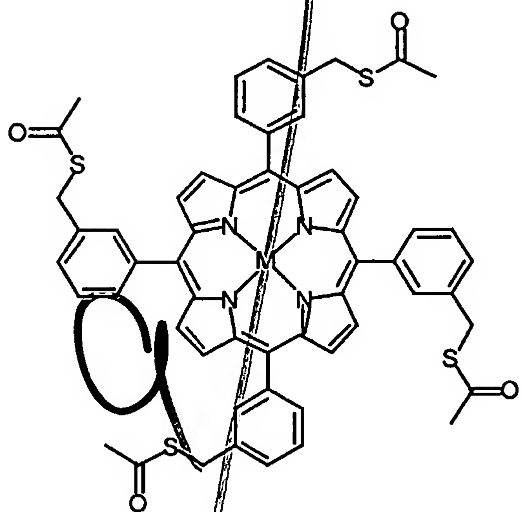


M = H,H; Zn



M = H,H; Zn

and



M = H,H; Zn

172. An apparatus for storing data, said apparatus comprising:

a fixed electrode electrically coupled to a storage medium comprising a storage molecule comprising a first subunit and a second subunit wherein the first and second subunits are tightly coupled such that oxidation of the first subunit alters the oxidation potential of the second subunit.

173. The apparatus of claim172, wherein the subunits are selected from the group consisting of a porphyrinic macrocycle, a metallocene, a linear polyene, a cyclic polyene, a heteroatom-substituted linear polyene, a heteroatom-substituted cyclic polyene, a tetrathiafulvalene, a tetraselenafulvalene, a metal coordination complex, a buckyball, a

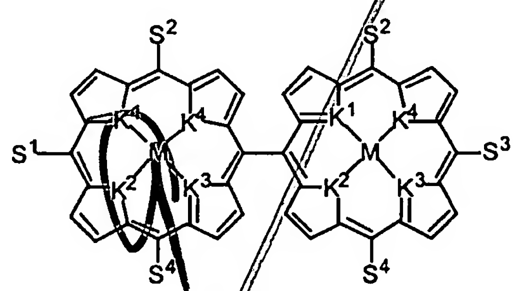
triarylamine, a a1,4-phenylenediamine, a xanthene, a flavin, a phenazine, a phenothiazine, an acridine, a quinoline, a 2,2'-bipyridyl, a 4,4'-bipyridyl, a tetrathiotetracene, and a *peri*-bridged naphthalene dichalcogenide.

174. The apparatus of claim 173, wherein the subunits are both porphyrinic macrocycles or metallocenes.

175. The apparatus of claim 173, wherein the subunits are both ferrocenes.

176. The apparatus of claim 173, wherein the subunits are both porphyrinic macrocycles.

177. The apparatus of claim 173, wherein a pair of the tightly coupled subunits has the following structure:



wherein S^1, S^2, S^3, and S^4 are substituents independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts, or one or more of S^1, S^2, S^3, and S^4 are -L-X where -L-X, when present is optionally present on one or both subunits and L, when present, is a linker;

X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate;

M is a metal; and

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, O, S, Se, Te, and CH.

178. The apparatus of claim 177, wherein M is selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Al, Pb, Ga, Fe, and Sn.

179. The apparatus of claim 177, wherein M is selected from the group consisting of Zn, Mg, and (H,H).

180. The apparatus of claim 177, wherein S^1, S^2, and S^3 are independently selected from the group consisting of mesityl, C_6F_5, 2,4,6-trimethoxyphenyl, phenyl, *p*-tolyl, *p*-(*tert*-butyl)phenyl, 3,5-dimethylphenyl, 3,5-di(*tert*-butyl)phenyl, 3,5-dimethoxyphenyl, 3,5-dialkoxyphenyl, and *n*-pentyl.

181. The apparatus of claim 177, wherein X is selected from the group consisting of $SCOR^1$, and $SCON(R^2)(R^3)$, wherein R^1, R^2, and R^3 are independently selected groups.

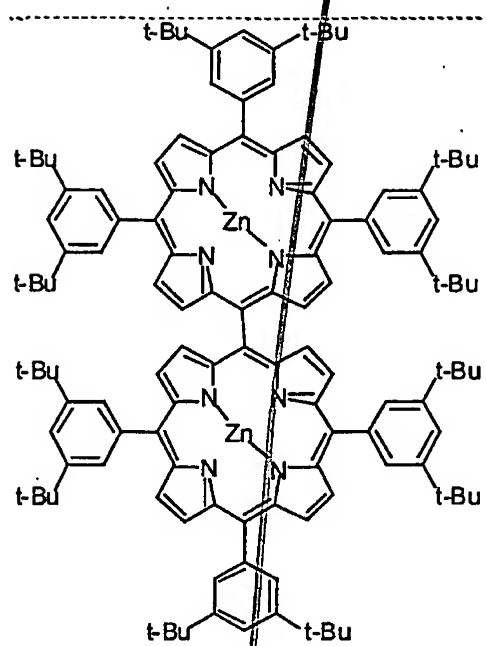
182. The apparatus of claim 177, wherein X is selected from the group consisting of SCN, SCONH(Et), $SCOCH_3$, and SH.

183. The apparatus of claim 177, wherein L-X is selected from the group consisting 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, 2-(4-mercaptophenyl)ethynyl, 2-(4-hydroselenophenyl)ethynyl, 2-(4-hydrotellurophenyl)ethynyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

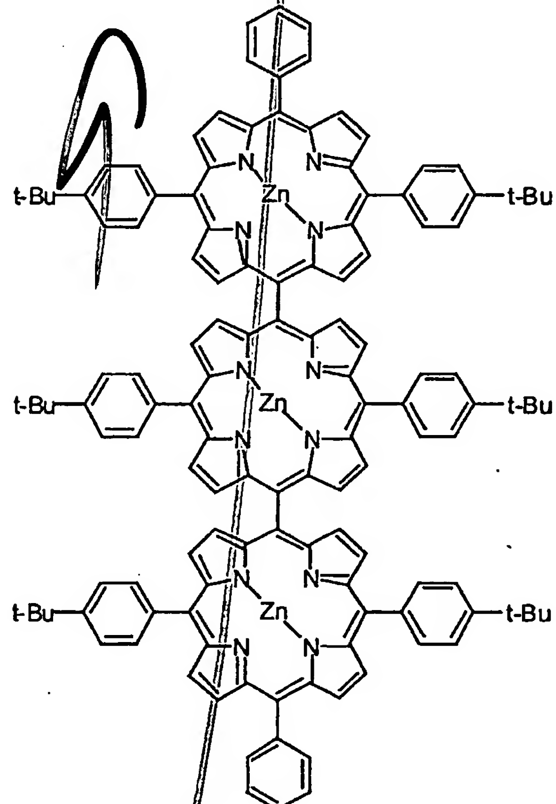
184. The apparatus of claim 177, wherein
S^1 and S^3 are both the same; and
K^1, K^2, K^3, and K^4 are all the same.

185. The apparatus of claim 184, wherein
M is Zn; and
K^1, K^2, K^3, and K^4 are all N.

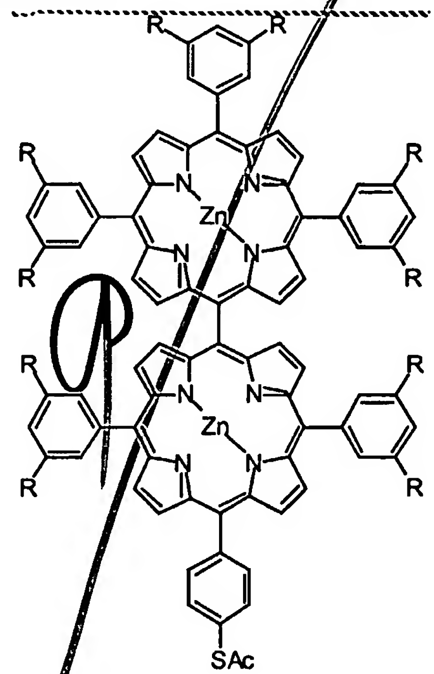
186. The apparatus of claim 184, wherein a pair of the tightly coupled subunits has the following structure:



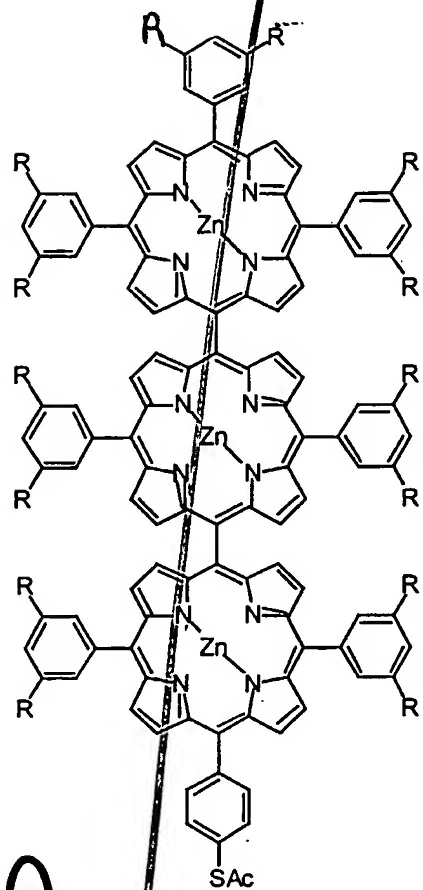
187. The apparatus of claim 184, wherein a pair of the tightly coupled subunits has the following structure:



188. The apparatus of claim 184, wherein a pair of the tightly coupled subunits has the following structure:



189. The apparatus of claim 184, wherein a pair of the tightly coupled subunits has the following structure:



190. The apparatus of claim 172, wherein said storage medium has at least three different and distinguishable non-neutral oxidation states.

191. The apparatus of claim 172, wherein said storage medium has at least eight different and distinguishable oxidation states.

192. The apparatus of claim 172, wherein said storage molecule is covalently linked to said electrode.

193. The apparatus of claim 172, wherein said storage molecule is electrically coupled to said electrode through a linker.

194. The apparatus of claim 172, wherein said storage molecule is covalently linked to said electrode through a linker.

195. The apparatus of claim 194, wherein said linker is a thiol linker.

196. The apparatus of claim 172, wherein said storage medium is juxtaposed in the proximity of said electrode such that electrons can pass from said storage medium to said electrode.

197. The apparatus of claim 172, wherein said storage medium is juxtaposed to a dielectric material imbedded with counterions.

198. The apparatus of claim 172, wherein said storage medium and said electrode are fully encapsulated in an integrated circuit.

199. The apparatus of claim 172, wherein said storage medium is electronically coupled to a second fixed electrode that is a reference electrode.

200. The apparatus of claim 172, wherein said storage medium is present on a single plane in said device.

201. The apparatus of claim 172, wherein said storage medium is present at a multiplicity of storage locations.

202. The apparatus of claim 201, wherein said storage locations are present on a single plane in said device.

203. The apparatus of claim 201, wherein said apparatus comprises multiple planes and said storage locations are present on multiple planes of said device.

204. The apparatus of claim 201, wherein said storage locations range from about 1024 to about 4096 different locations.

205. The apparatus of claim 204, wherein each location is addressed by a single electrode.

206. The apparatus of claim 204, wherein each location is addressed by two electrodes.

207. The apparatus of claim 172, wherein said electrode is connected to a voltage source.

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208. The apparatus of claim 207, wherein said voltage source is the output of an integrated circuit.

209. The apparatus of claim 172, wherein said electrode is connected to a device to read the oxidation state of said storage medium.

210. The apparatus of claim 209, wherein said device is selected from the group consisting of a voltammetric device, an amperometric device, and a potentiometric device.

211. The apparatus of claim 210, wherein said device is an impedance spectrometer or a sinusoidal voltammeter.

212. The apparatus of claim 209, wherein said device provides a Fourier transform of the output signal from said electrode.

213. The apparatus of claim 209, wherein said device refreshes the oxidation state of said storage medium after reading said oxidation state.

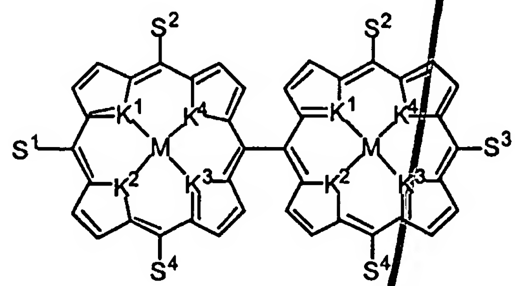
214. The apparatus of claim 172, wherein the second subunit can be oxidized by a voltage difference no greater than about 2 volts.

215. An information storage medium, said storage medium comprising one or more storage molecules such that said storage medium has at least two different and distinguishable non-neutral oxidation states, wherein the storage molecules comprise a first subunit and a second subunit wherein the first and second subunits are tightly coupled such that oxidation of the first subunit alters the oxidation potential of the second subunit, wherein said subunits are selected from the group consisting of a porphyrinic macrocycle and a metallocene and said molecule has at least two different non-zero oxidation states and said oxidation states are within a redox potential range of less than about 2 volts.

216. The molecule of claim 215, wherein the subunits are both ferrocenes.

217. The molecule of claim 215, wherein the subunits are both porphyrinic macrocycles.

218. The molecule of claim 215, wherein said storage molecule comprises a pair of the tightly coupled subunits has the following subunits has the following structure:



wherein S^1, S^2, S^3, and S^4 are substituents independently selected from the group consisting of aryl, phenyl, cycloalkyl, alkyl, halogen, alkoxy, alkylthio, perfluoroalkyl, perfluoroaryl, pyridyl, cyano, thiocyanato, nitro, amino, alkylamino, acyl, sulfoxyl, sulfonyl, imido, amido, and carbamoyl wherein said substituents provide a redox potential range of less than about 2 volts, or one or more of S^1, S^2, S^3, and S^4 are -L-X where -L-X, when present is optionally present on one or both subunits and L, when present, is a linker;

X is selected from the group consisting of a substrate, a reactive site that can covalently couple to a substrate, and a reactive site that can ionically couple to a substrate;

M is a metal; and

K^1, K^2, K^3, and K^4 are independently selected from the group consisting of N, O, S, Se, Te, and CH.

219. The molecule of claim 218, wherein M is selected from the group consisting of Zn, Mg, Cd, Hg, Cu, Ag, Au, Ni, Pd, Pt, Co, Rh, Ir, Mn, B, Al, Pb, Ga, Fe, and Sn.

220. The molecule of claim 218, wherein M is selected from the group consisting of Zn, Mg, and (H,H).

221. The molecule of claim 218, wherein S^1, S^2, and S^3 are independently selected from the group consisting of mesityl, C_6F_5, 2,4,6-trimethoxyphenyl, phenyl, *p*-tolyl, *p*-(*tert*-butyl)phenyl, 3,5-dimethylphenyl, 3,5-di(*tert*-butyl)phenyl, 3,5-dimethoxyphenyl, 3,5-dialkoxyphenyl, and *n*-penty.

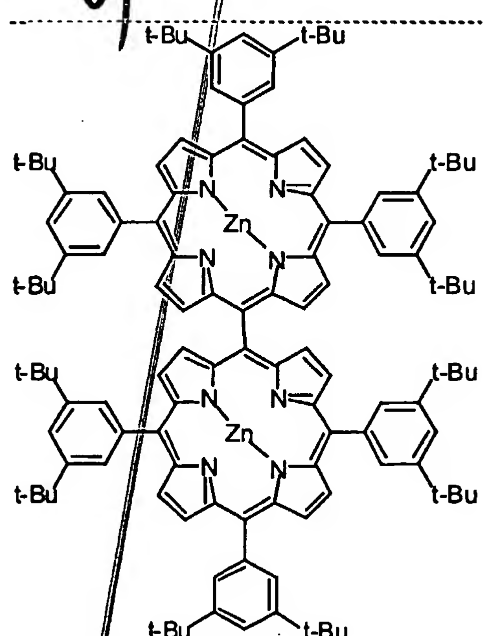
222. The molecule of claim 218, wherein X is selected from the group consisting of SCN, SCONH(Et), $SCOCH_3$, and SH.

223. The molecule of claim 218, wherein L-X is selected from the group consisting of 4-(2-(4-mercaptophenyl)ethynyl)phenyl, 4-mercaptomethylphenyl, 4-hydroselenophenyl, 4-(2-(4-hydroselenophenyl)ethynyl)phenyl, 4-hydrotellurophenyl, 2-(4-mercaptophenyl)ethynyl, 2-(4-hydroselenophenyl)ethynyl, 2-(4-hydrotellurophenyl)ethynyl, and 4-(2-(4-hydrotellurophenyl)ethynyl)phenyl.

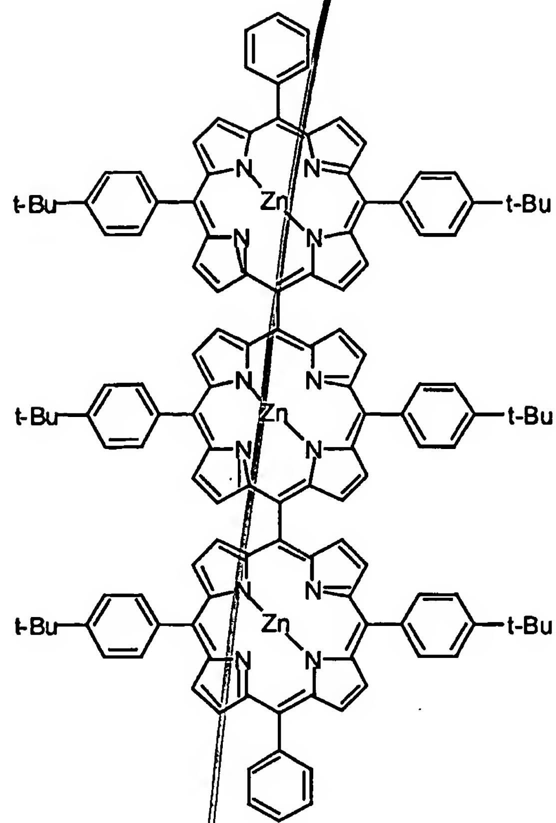
224. The molecule of claim 218, wherein
S^1 and S^3 are both the same; and
K^1, K^2, K^3, and K^4 are all the same.

225. The molecule of claim 224, wherein
M is Zn; and
K^1, K^2, K^3, and K^4 are all N.

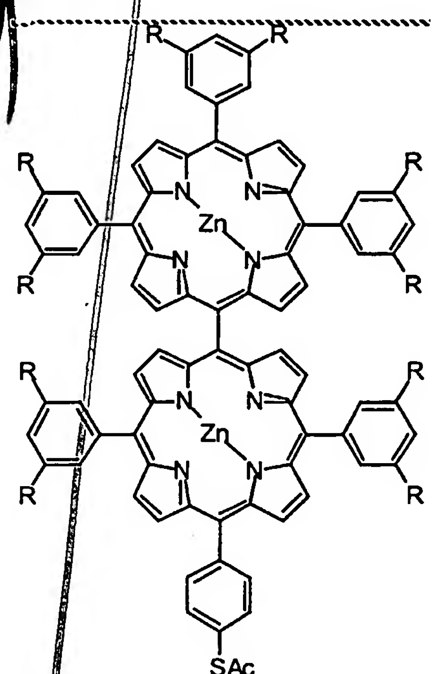
226. The molecule of claim 224, wherein a pair of the tightly coupled subunits has the following structure:



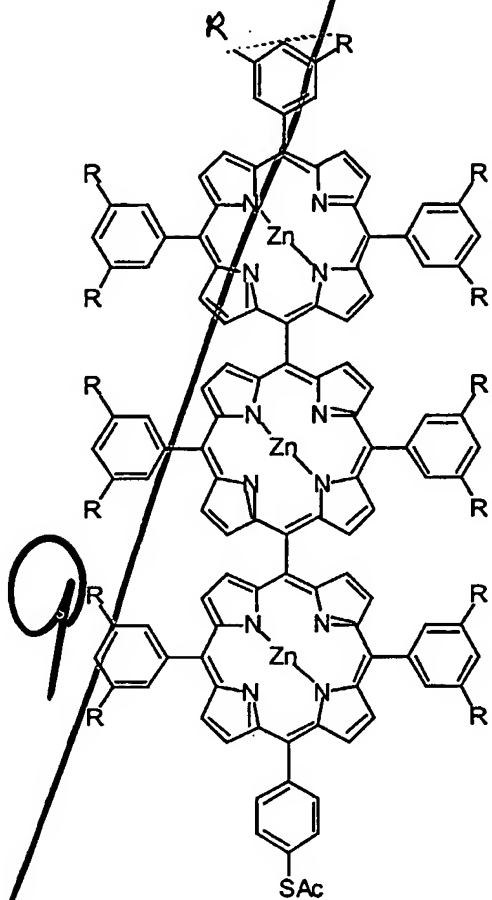
227. The molecule of claim 224, wherein a pair of the tightly coupled subunits has the following structure:



228. The molecule of claim 224, wherein a pair of the tightly coupled subunits has the following structure:



229. The molecule of claim 224, wherein a pair of the tightly coupled subunits has the following structure:



230. The molecule of claim 218, wherein said storage medium has at least three different and distinguishable non-neutral oxidation states.

231. The molecule of claim 218, wherein said storage medium has at least eight different and distinguishable oxidation states.

232. A method of storing data, said method comprising:

i) providing an apparatus according to claim 172; and

ii) applying a voltage to said electrode at sufficient current to set an oxidation state of said storage medium.

233. The method of claim 232, wherein said voltage ranges up to about 2 volts.

234. The method of claim 232, wherein said voltage is the output of an integrated circuit.

235. The method of claim 232, wherein said voltage is the output of a logic gate.

236. The method of claim 232, further comprising detecting the oxidation state of said storage medium and thereby reading out the data stored therein.

237. The method of claim 236, wherein said detecting the oxidation state of the storage medium further comprises refreshing the oxidation state of the storage medium.

238. The method of claim 236, wherein said detecting comprises analyzing a readout signal in the time domain.

239. The method of claim 236, wherein said detecting comprises analyzing a readout signal in the frequency domain.

240. The method of claim 239, wherein said detecting comprises performing a Fourier transform on said readout signal.

241. The method of claim 236, wherein said detecting utilizes a voltammetric method.

242. In a computer system, a memory device, said memory device comprising the apparatus of claim 172.

243. A computer system comprising a central processing unit, a display, a selector device, and a memory device, said memory device comprising the apparatus of claim 172.